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EFFECT OF SCREEN MESH WICK AND AL_2O_3 NANOFLUID CONCENTRATION ON CIRCULAR HEAT PIPE PERFORMANCE

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ABSTRACT

It is a passive heat transfer device that is used to remove the amount of heat from the heat source. The behavior of screen wick and nanofluid to improve the performance of a heat pipe.Al_2O_3/DI-water based nanofluid is utilized as a working fluid. An exploratory arrangement is planned and built to think about the heat pipe execution under various working conditions. The effect of filling ratio, the volume fraction of nano-particle in the base fluid, screen mesh as wick and heat input rate on the thermal resistance is investigated. The total thermal resistance of the heat pipe for Al_2O_3/DI-water based nanofluid is also predicated. An experimental correlation is obtained to predict the influence of heat transfer rate, Kq on the thermal resistance. Thermal resistance diminishes with expanding Al_2O_3/DI-water based nanofluid contrasted with that of pure water. The experimental data is compared to the available data from previous work. The range of operating parameters of nanofluid concentrations [0.05%vol, 0.15%vol, 0.25%vol] and heat rate [50,100,150,200,250] watts.

KEYWORDS: Thermal Performance, Heat Pipe, Aluminum Oxide, Nanofluids & Screen Mesh Wick Type

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Original Article

1. INTRODUCTION

To take care of the developing issue of heat generation by electronic equipment, two-stage change gadget, for example, heat pipe and thermosyphon cooling system are presently utilized in the electronic industry. Heat pipe is uninvolved gadgets that transport heat from a heat source to a heat sink over generally long separations by using the latent heat of vaporization of a working liquid. The heat pipe for the most part comprises of three segments; evaporator, adiabatic area and condenser. In the evaporator, the working liquid vanishes as it retains a measure of heat proportional to the inert heat of vaporization. The working liquid vapor condenser and afterward, return to the evaporator. Nanofluids, delivered by suspending nano-particles with normal sizes beneath 100nm in traditional heat transfer move liquids, for example, water and ethylene glycol give new working liquids that can be utilized in heat pipe. Avery modest quantity of visitor nano-particles, when consistently and suspended steadily in host liquids, can give a sensational improvement in working liquid thermal properties. The objective of utilizing Nanofluids is to accomplish the most astounding conceivable thermal properties utilizing the littlest conceivable volume division of the nano-particles.

There has been of enthusiasm for the utilization of heat pipe for thermal administration because of expanding heat flux prerequisites and thermal imperatives in numerous modern applications. At the point when all is said in done, the introduction of a heat pipe depends upon its geometry, working fluid and thin wicking material, working temperature, and associated heat transition [1]. The advance of smaller scale hardware and miniaturized

scale fabricate advances causes it conceivable to deliver more to exceptionally performed and coordinated electronic gadgets. Seek after of this objective, in any case, brings a heat transfer emergency that ingests numerous scientists in the heat transfer field, Since the 90's of the twentieth century, analysts started to apply the nano-material innovation to the field of heat transfer enhancement [3]. Heat channels are high-effective heat transfer gadgets and have been broadly connected in different thermal frameworks. Since heat pipe uses the stage change of the working liquid to move the heat, the determination of working liquid is of fundamental significance to advance the thermal presentation of the heat pipe. Illuminated by the upgraded heat transfer impact of Nanofluids in the single stage and stage changing heat transfer, a few scientists have connected different Nanofluids in heat pipes as the working liquids to improve their heat transfer execution. Heat pipe and their applications in thermal administration have been read for quite a long time. They establish an effective, minimal apparatus to disseminate generous measure of heat from different engineering frameworks including electronic segments. Heat pipe can scatter significant measure of heat with a generally little temperature drop along the heat pipe while giving a self-siphoning capacity because of an implanted permeable material in their structure. A restricting element for the heat transfer capacity of a heat pipe is identified with the working liquid vehicle properties. To defeat this impediment, the thermo physical properties of the liquid can be improved [4]. There has been recharged enthusiasm for the utilization of heat pipes for thermal administration because of expanding heat flux transition prerequisites and thermal limitations in numerous modern applications. The presentation of heat pipes is portrayed both by the powerful thermal resistance and the most extreme heat transport limit. The greatest heat transport in moderate temperature applications is restricted by the fine weight that can be produced by the wick structure [5]. The scaled down or smaller scale heat pipe has been connected as a solid and proficient gadget for a long time to cool miniaturized scale electronic gadgets, for example, CPUs of scratch pad PCs. In the advancement history of heat pipes, numerous sorts, for example, the thermosyphon, pulsating heat pipe, Capillary Pumped Loop (CPL), Loop Heat Pipe (LHP), Grooved heat pipe, and micro heat pipe, have developed inferable from the knowledge of their architects [6]. Fluid heating and cooling assume significant jobs in numerous ventures including power stations, production procedures, transportation and electronics. The writing revealing heat transfer upgrade strategies in various procedures are abundant. A large portion of these techniques depend on structure variety and among them heat surface area addition (fins), vibration of heated surface, injection or suction of liquid and applying electrical or magnetic fields can be cited [7]. Due to higher thickness of chips and plan of electronic segments with increasingly, minimized makes heat transfer progressively troublesome. Therefore, heat pipe has been utilized in a wide assortment of utilizations in the electronic parts with a rapid and abnormal state of heat generation. There are numerous specialists displayed the heat transfer attributes of the heat pipe [10]. A Loop Heat Pipe (LHP) is an exceptionally successful two-stage fine siphoned heat transfer gadget which comprises of an evaporator, compensation chamber, vapor and fluid lines and condenser. A point by point audit of the principle qualities of LHPs can be found with expanding power densities of electronic gadgets, the LHP innovation keeps on being a significant territory of research and there is a requirement for exact transient numerical models. The LHP activity includes complex heat and mass transfer procedures rendering the scientific displaying exceptionally challenging [14]. Loop heat pipes (LHPs) are profoundly productive heat transfer gadgets with an impressive potential for improvement and application in different fields. At present LHPs are effectively utilized in space designing. Normally these gadgets have a cylindrical shaped evaporator from 12 to 28 mm in measurement. The shape and the size of the condenser might be very extraordinary relying upon the methods and states of its cooling. The length of the vapor and the fluid lines interfacing the evaporator and the condenser can arrive at 10 m and more, and their diameter is, when in doubt, in the range from 3 to 8 mm. The absence of a wick in these lines makes them simple to twist giving them the required shape. Another significant preferred position of LHPs is

their low sensitivity to the difference in direction in 1-g conditions [16]. Air cooling arrangement which contains a fan and heat sink is utilized to expel heat produced by electronic gadget for security and lifespan. To comprehend the developing heat generated by electronic gadgets, two-stage change gadgets (e.g. heat pipe, loop heat pipe, thermosyphon cooling system) become main cooling technologies in the electronic industry [17].

2. PREPARATION OF NANOFLUID

Nanofluids are widely organized by two-step approach and it's far the most monetary method to have large scale production. The present work follows the 2-step approach. In this method, Al_2O_3 nanoparticles have been synthesized and then dispersed in base fluid with the assist of ultrasonication as shown in Figure 1. The well known trouble encountered in the system of nanofluid is that easy blending can't reap a stable nanoparticles suspension. Therefore, in the present have a look at, an ultrasonic processor became hired for that motive. The impact of dispersing energy (ultrasonication) ultrasonic waves was used to efficiently disperse and breakdown agglomerated nanoparticles inside the base fluids. The applied device changed into probe type sonicator. The ultrasonic dismembrator makes use of ultrasonic vibrations to very well combine and suspend the nanoparticles in the base fluid. The power delivery system for the sonic dismembrator converts the power from AC line voltage to 20 kHz electric energy. The energy is then fed to another converter, consisting of a lead zirconate, titanate, electrostrictive element, which expands and contracts with alternating voltage producing mechanical vibrations inside the longitudinal course. This travels to the horn tip and creates cavitations inside the nanofluid and this causes the suspension to become energized. The Ultrasonic wave's produced electrostatic repulsive forces ought to be installed between debris. Both binary base fluids combinations and binary Nanofluids samples have been sonicated for 20 minutes. The sonication is executed in an ice bath to keep a consistent temperature in the suspension and for homogenization of Nanofluids. Ultrasonication is used mainly to keep away from the agglomeration of nanoparticles and to supply properly-dispersed strong suspension.

Figure 1: Ultra Sonicator.

Figure 2: Nanofluid Preparation.

3. EXPERIMENTAL SETUP AND PROCEDURE

A schematic configuration of the investigate gear is shown in Figure 3. This test grasps unadulterated water and Al_2O_3/DI-water based nanofluid as working liquid. The size of the nanoparticles is underneath 50nm. The test nanofluid is picked up by this method for using dissipating the nanoparticles in unadulterated water. The running fluid is charged by method for the charging line. In heat pipe, heat is delivered the utilization of electric more smoking and it is adjusted through the radiator. The vapor is made inside the evaporator section is moved toward the condenser divide through the adiabatic chamber whose length and diameter are 50 mm and 12.7 mm independently. Both evaporator and condenser area have the parts of 12.7 mm separation crosswise over and time of evaporator is 100 mm and a range of condenser is 150 mm in a steady progression. The condensate is approved to return lower back to evaporator arrange with the guide of thin intrigue "wick structure" with the guide of adiabatic chamber. The surfaces of the evaporator stage, adiabatic stage, and condenser area perspectives are verified with ceramic fiber material.

Chromel-alumel thermocouples (T-type) are glued to the heat pipe ground and dispensed adjacent its range to degree the region temperatures. All thermocouples are associated with a virtual temperature recorder by utilizing a multi-point switch. The non condensable gases are exhausted through a vacuum siphon. The heat pipe is discharged u to 0.01bar with the guide of the vacuum line. The imperativeness provided for the electric radiator is normal with the manual of a multi-meter. The information voltage altered into adjusted the usage of an autotransformer. The voltage drops sooner or later of the radiator were varied from 50 to 250 volts. The A.C voltage stabilizer is used to ensure that there is most likely no voltage fluctuation all through tests. The pressure inside the evaporator is measured by a pressure gage with a resolution of 0.01bar. Chilled water is used for cooling the condenser area in a constrained convection

Thermocouples are dispersed near to the surfaces of the heat pipe level as follows: four thermocouples are connected in the evaporator part, thermocouples are connected in the adiabatic stage and 4 thermocouples are attached inside the condenser degree. The obtained information for temperatures and data warm temperature cost are figure the warm obstacle. One can outline the filling rate, in gentle of the way that the amount of charged fluid to the general evaporator certificate. The working fluid is charged at 30 ˚C. The results of working fluid sort, filling share, amount fraction of nano-particles inside the base fluid, wide accumulation of wick layers and heat input rate on the thermal performance as a rule execution of heat pipe are explored inside the test work. The investigate runs are cultivated with the guide of the accompanying advances:

- The heat pipe is exhausted and blamed for a particular amount of working fluid.
- The equipped electric power is adjusted substantially at a favored rate utilizing autotransformer.
- The normal state circumstance is done after, around, 20 minutes of strolling time the use of central adjustments to the enter heat rate temperature cost. Resulting to completing the unfaltering country situation, the separating of thermocouples is recorded, successively. The voltage of the heater is measured to choose the expense of heat flux. At shutting, the worry inside the evaporator is recorded.
- At the end of each run power is changed and step 3 is repeated
- Pure water and Al_2O_3/DI-water based nanofluid are used as running fluids. Steps 1 through4 are repeated for Al_2O_3/DI-water based nanofluid the use of a couple of estimations of volume parts of nano-particles. The sum parts connected are 0.05%, 0.15% and 0.25% independently.

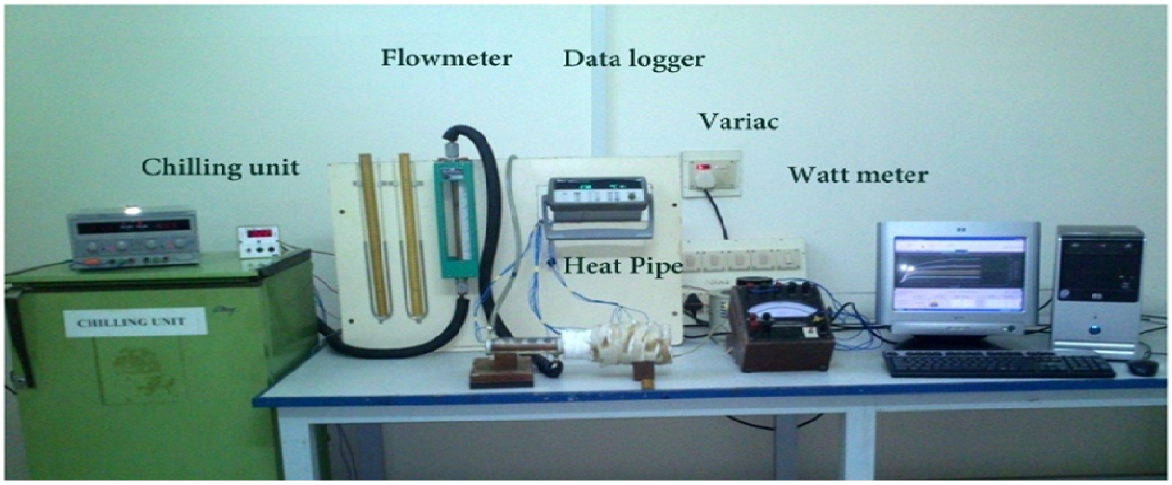

Figure 3: View of Experimental Setup.

The assessments are developed with the heat pipe inside the level course. The heat duty to the evaporator is ventured forward in undertakings of 50 W simultaneously as the temperature of the coolant is situated away reliable at 18℃. The temperature is distributed along the heat pipe is anticipated and recorded at the normal circumstance. In light of the temperatures anticipated. The exploratory alliance obliges a mission radiator (top notch essentialness yield of 1000 W), Watt meter and a variable transformer to give required vitality the guide of the more sweltering. The actualities checking framework comprises of an information experiences logger (Agilent) and a PC structure to record the estimations. T-type thermocouples are utilized to degree the temperature response at different heat pipe areas. The inlet and outlet temperatures of the cooling water have additionally foreseen the use of T-type thermocouples.

The stream charge of the cooling water is envisioned while the heat pipe works reliably. The heat pipe with base liquid and Nanofluids are attempted for the heat estimations moving from a 100 W to 200 W. The adiabatic level, the quality convey to the deterrent radiator unit is developed to move toward becoming on. The heat input has differentiated the utilization of the variable transformer from a 100 W to 200 W. Temperatures at explicit locales of the heat pipe and input and outlet temperatures of the cooling water are checked with the guide of technique for the data obtainment unit. The mass development rhythm of cooling water on the condenser is assessed while the heat pipe works at regular state.

The 50 watts of power passing in a heat pipe with the assistance of the ammeter and voltmeter. The power is passed in a heat pipe then the temperature of the heat pipe is raised. All of the temperatures in the heat pipe are presumably communicated in a prohibited section. The astounding is most likely extended in a 100 W, 150 W and 200 W. The best stimulated then the heat moved value in like manner improved and blurred in a thermal resistance. To decrease the thermal resistance check and creating inside the remarkable thermal conductivity of screen mesh wick heat pipe.

4. RESULTS AND DISCUSSIONS

The temperatures recorded for the heat pipes using Al_2O_3/DI-water Nanofluids of concentrations should be 0.05 vol. % and 0.25 vol. % were found to be less than those of the heat pipe with pure water. While analyzing the temperature of the heat pipe using 0.05 vol.% concentration of Al_2O_3/DI-water nanofluid, it was observed that, as the heat load increases from 50 W to higher heat loads the wall surface temperature and vapor core temperature were increased at a higher rate compared to pure water heat pipe.

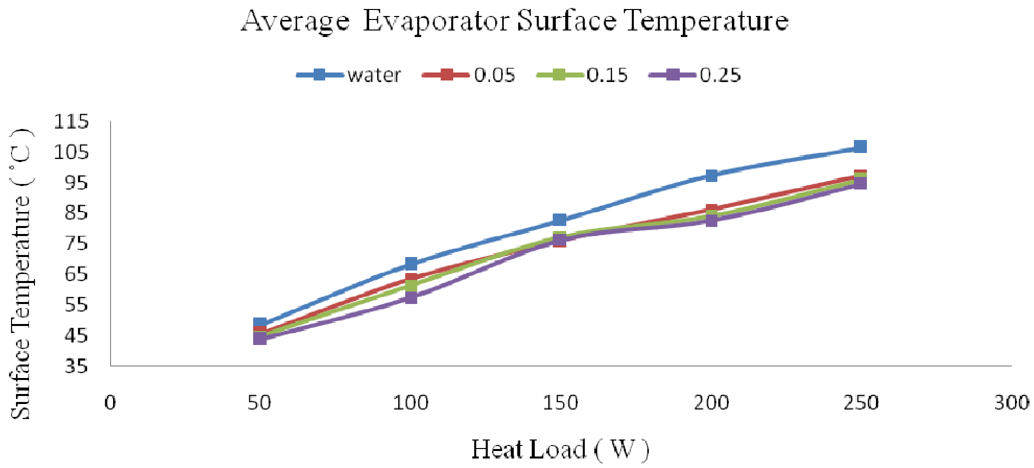

Figure 4.1: Average Evaporator Surface Temperature.

The amount of Nano powder required to prepare the nanofluid increases from 0.05 vol. % concentration to 0.25 vol. %. As the volume concentration will increase, because of the growth in the quantity of Nano powder used for the practice, the nanofluid will become extra viscous and in the end will increase its fluid density. This impacts the transport properties of the running fluid and creates a better drift resistance. Because of this reason, the performance of the heat pipe the use of 0.5 vol. % of Al_2O_3/DI-water nanofluid heat pipe became inferior in comparison to a pure water heat pipe. The main intention of the usage of Nanofluids is to have a reduced surface temperature in comparison with conventional running fluids. For this reason, for further evaluation the Nanofluids with 0.05 and 0.25 vol. % concentrations only were used, for the reason that they showed better performance.

As explained in advance the wall surface temperature in the evaporator, adiabatic and condenser areas had been recorded for all of the three heat pipes for various heat inputs. It is found that for all of the applied heat loads the temperature distribution of the heat pipe using both concentrations of Nanofluids is low as compared with pure water heat pipe. Out of the three heat pipes tested, the heat pipe with nanofluid having 0.05 vol. % concentration confirmed the lowest surface as well as vapor temperatures in all of the experiments.

The heat transfer functionality and the thermal performance of heat pipes depend upon the wall surface temperature distribution. Figures 4.1 give the distribution of wall surface temperature of the heat pipe along the axial duration starting from the evaporator region until the condenser region at various heat loads (100 W, 150 W, 200 W and 250 W). In order to measure the temperature at evaporator surface thermocouples had been used. The common evaporator surface temperatures were predicted.

The average evaporator surface temperature and adiabatic surface temperatures drop by 7.8% and 5.59% respectively at 100 W heat loads for 0.05 vol. % Al_2O_3/DI-water nanofluid. These temperatures drop have been 12.65% and 12.90% respectively for 0.25 vol. % Al_2O_3/DI-water nanofluid heat pipes, as compared with pure water heat pipe. At 150 W heat load the reduction in temperature is 8.75%, 6.51% for 0.05 vol. % Al_2O_3/DI-water nanofluid and 15.25%, 14.37% for 0.25 vol. % Al_2O_3/DI-water nanofluid. Similarly a discount in temperature measurements of 15.34% and 12.95% for 0.05 vol. % Al_2O_3/DI-water nanofluid and 17.81% and 17.48% for 0.25 vol. % Al_2O_3/DI-water Nanofluids were determined at 200 W heat loads as compared to pure water heat pipe.

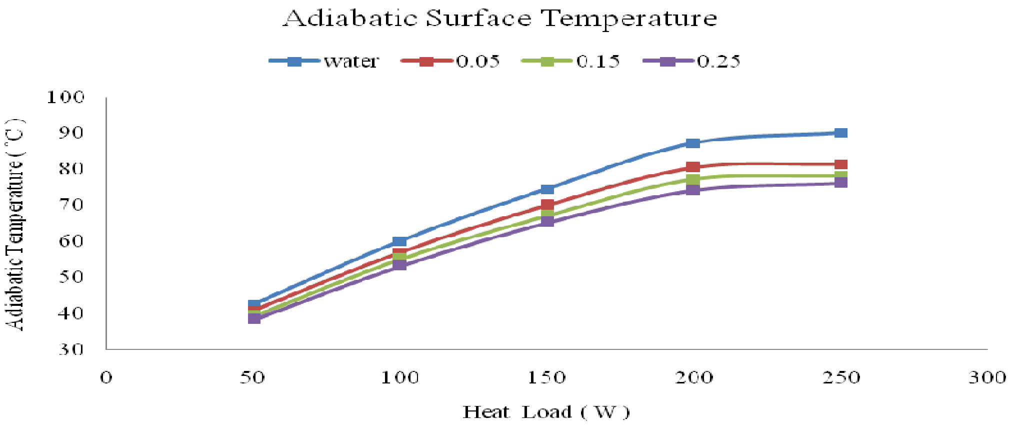

Figure 4.2: Adiabatic Surface Temperature.

General five thermocouples have been used for the surface temperature size, two at evaporator one at adiabatic and at condenser region. The average of five thermocouples suggests the average surface temperature. From Figure 4.1a most drop of 12.76**%** in average surface temperature was received for 0.05 vol. %Al_2O_3/DI-water nanofluid on the most heat load of 200 W, in which as in the case of 0.25 vol. % Al_2O_3/DI-water nanofluid 17.81% reduction in surface temperature is acquired compared with pure water heat pipe. Those experiments correctly quantify the drop in evaporator and adiabatic temperatures and average surface temperatures under different load conditions.

Figure 4.1 offers a consolidation of comparison of average surface temperatures within the evaporator area, for different fluids. The giant drop in temperature is evident. A most of 6.11**%** drop is seen for the very best heat loads considered within the gift observe for 0.05vol. %Al_2O_3/DI-water nanofluid and 10.48**%** drop is located for 0.25volume % Al_2O_3/DI-water nanofluid and 10.48**%** drop is located for 0.25volume % Al_2O_3/DI-water nanofluid. Whilst the Al_2O_3 nanoparticles had been dispersed with pure water, the temperature for the duration of the heat pipe surface also reduced substantially.

The studies of in advance researchers have shown that, the addition of nanoparticles in base fluid can increase the thermal conductivity of the base fluid. In all of the cases taken into consideration, the drop in temperature happened due to the improved thermal conductivity of Al_2O_3/DI-water nanofluid which improves its heat carrying capacity. The comparative look at of the temperature distribution of the surface in the heat pipe's surface core is any other indicator for the overall performance of heat pipe. But, the surface temperature distribution can also be related to the temperature distribution of the vapor. A figure 4.1 represents the distribution of temperature at vapor core of the heat pipes alongside the axial length from evaporator area to the condenser location at various heat loads (50 W, 100 W, 150 W, 200 W and 250 W).

The evaporator common temperature of the surface and adiabatic temperature of surface drops by way of 6.11% and 4.3% respectively at a 50 W heat load for 0.05 vol. % Al_2O_3/DI-water nanofluid and 10.48% and 11.2% respectively for 0.25 volume % Al_2O_3/DI-water nanofluid compared with Pure water. At 100 W heat load the discount in temperature is 7.83 % and 5.59% for 0.05 volume % Al_2O_3/DI-water nanofluid and 12.65% and 12.90% for 0.25 volume % Al_2O_3/DI-water nanofluid. In addition a discount in temperature measuring 8.75% and 6.5% for 0.05 volume % Al_2O_3/DI-water nanofluid and 15.25% and a 14.37% for 0.25 volume % Al_2O_3/DI-water nanofluid is located at 150 W and subsequently a reduction in temperature measuring 12.7% and 8.36% for 0.05 volume % Al_2O_3/DI-water nanofluid and 17.81% and 17.48% for 0.25 volume % Al_2O_3/DI-water nanofluid is found on the most heat load, 200 W in comparison to Pure water heat pipe.

It is really located that the reduction in surface temperature is because of the excessive thermal conductivity of the Al_2O_3 Nano powder which displays inside the heat sporting capacity of Al_2O_3 nanofluid. But as the concentration of nanofluid will increase, its thermal performance decreases due to the growth in fluid density and its transport properties. This is why the performance of 0.05 volume % Al_2O_3 Nanofluids is higher than that of 0.25 volume % Al_2O_3 nanofluid.

The difference in wall surface temperature of evaporator and condenser in a heat pipe performs a considerable position in making sure its thermal overall performance. Lesser this quantity, the extra can be its heat delivery functionality. From Figure 4.1 within the case of difference in wall surface temperature of evaporator and condenser a discount of 12.7% is observed for 0.05 volume % Al_2O_3 nanofluid heat pipe at 200 W. at the same heat load, a discount of 17.81% is found for 0.25 volume % Al_2O_3 nanofluid heat pipe in comparison to pure water heat pipe. This again suggests that the heat pipe having 0.05 volume % Al_2O_3 Nanofluids as working fluid is greener in its thermal performance equal trend changed into found.

Any other crucial performance parameter of heat pipe which defines its overall performance under the given heat load situations is its thermal resistance, described in figure 4.3. As the heat load increases the thermal resistance decreases. The thermal resistance of all the four heat pipes under investigation is shown within the figure 4.3. It is found that, for the maximum heat load taken into consideration inside the study, in comparison with pure water heat pipe, a reduction of 21.44% is determined within the case of the heat pipe having 0.25 volume % Al_2O_3 Nanofluids. For the heat pipe having 0.05 volume % Al_2O_3 nanofluid 15.87% reduction in thermal resistance is seen, which once more proved the wonderful thermal performance characteristics of 0.05 volume % Al2O3/DI-water Nanofluids as working fluid inside the heat pipe application.

Figure 4.4 gives some other performance parameter of a heat pipe specifically, effective thermal conductivity that's described in equation. As per this equation because the thermal resistance decreases the effective thermal conductivity must increase. This shows an inverse trend with respect to thermal resistance which in addition reinstates that 0.05 volume % Al_2O_3 Nanofluids is higher than 0.25 volume % nanofluid and pure water taken into consideration in the present study.

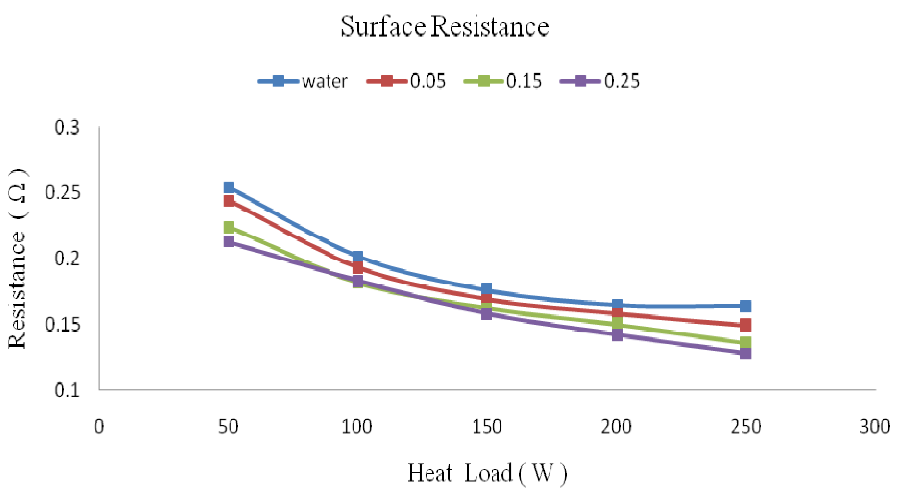

Figure 4.3: Surface Resistance.

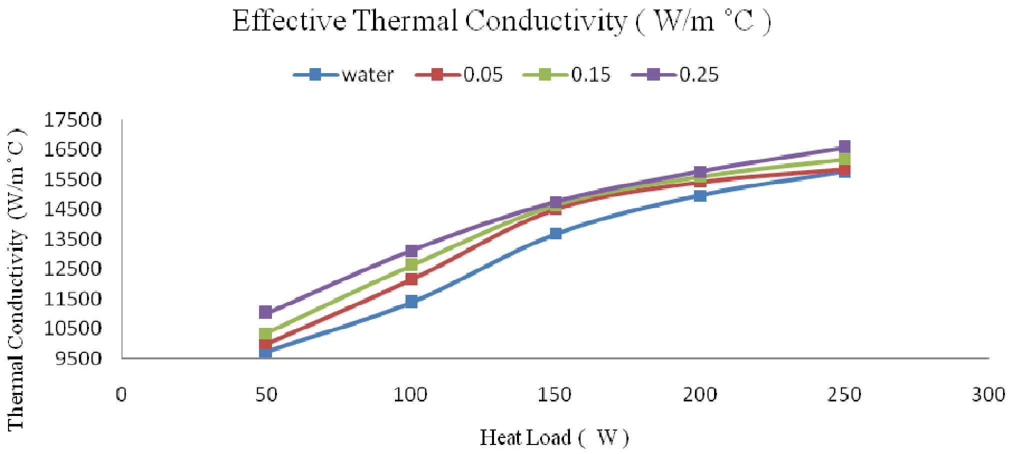

Figure 4.4: Effective Thermal Conductivity.

From figure 4.4 as shows that the effective thermal conductivity and heat load. The evaporator common temperature of surface and effective thermal conductivity temperature of surface increased by way of 6.1% and 2.74% respectively at a 50 W heat load for 0.05 volume % Al_2O_3/DI-water nanofluid and 10.48% and 11.74% respectively for 0.25 volume % Al_2O_3/DI-water nanofluid compared with Pure water. At 100 W heat load the discount in temperature is 7.8 % and 6.38% for 0.05 volume % Al_2O_3/DI-water nanofluid and 12.6% and 13.22% for 0.25 volume % Al_2O_3/DI-water nanofluid. In addition a discount in temperature measuring 8.75% and 5.71% for 0.05 volume % Al_2O_3/DI-water nanofluid and 15.2% and a 7.22% for 0.25 volume % Al_2O_3/DI-water nanofluid is located at 150 W and subsequently an increase in temperature measuring 12.7% and 2.9% for 0.05 volume % Al_2O_3/DI-water nanofluid and 17.81% and 5.07% for 0.25 volume % Al_2O_3/DI-water nanofluid is found on the most heat load, 200 W in comparison to pure water heat pipe.

From figure 4.5 as shows that the temperature difference between evaporator and condenser and heat load. The evaporator common temperature of surface and effective temperature difference of surface dropped by way of 6.11% and 10.47% respectively at a 50 W heat load for 0.05 volume % Al_2O_3/DI-water nanofluid and 10.4% and 11.9% respectively for 0.25 volume % Al_2O_3/DI-water nanofluid compared with Pure water.

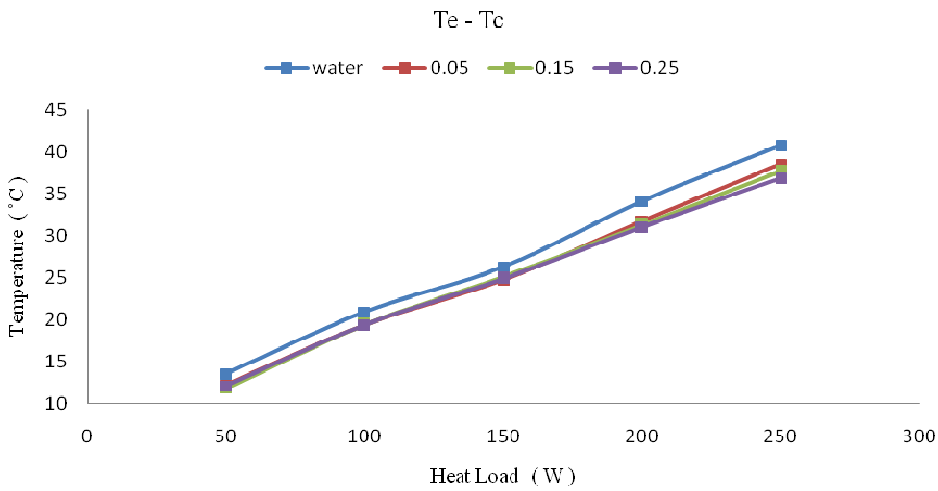

Figure 4.5: Temperature Difference between Evaporator and Condenser.

At 100 W heat load the discount in temperature is 7.83 % and 15.4% for 0.05 volume % Al_2O_3/DI-water nanofluid and 12.6% and 15.3% for 0.25 volume % Al_2O_3/DI-water nanofluid. In addition a discount in temperature measuring 8.75% and 18.3% for 0.05 volume % Al_2O_3/DI-water nanofluid and 15.25% and a 17.6% for 0.25 volume % Al_2O_3/DI-water nanofluid is located at 150 W and subsequently a increased in temperature measuring 12.76% and 18.87% for 0.05 volume % Al_2O_3/DI-water nanofluid and 17.81% and 21.44% for 0.25 volume % Al_2O_3/DI-water nanofluid is found on the most heat load, 200 W in comparison to Pure water heat pipe.

5. CONCLUSIONS

In this experimental work heat transfer performance of Al_2O_3/DI-water nanofluid as working fluid was experimentally analyzed in a heat pipe and results were compared with that of pure water heat pipe. From the results it is evident that as increasing nanofluid concentration (0.05 volume %, 0.15 volume %, 0.25 volume %) and heat load (50 W, 100 W, 150 W, 200 W) the surface temperature increased, thermal resistance decreased and increasing the thermal conductivity of heat pipe.

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